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能源轉型下需求面與分散式能源整合之商業模式

Business Model of Demand Side and Distributed Energy Resources Integration in the Energy Transition

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摘要

全球淨零與能源轉型趨勢下，再生能源、儲能、電動車等分散式能源(Distributed Energy Resources, DER)大量併入電網，DER 雖能作為有效資源，相較於傳統電廠不穩定、低可視性的特性，使得要維持系統供需平衡更加艱難。為使 DER 得到良好的管控與掌握，歐美先進國家已朝 DER 整合與虛擬電廠(Virtual Power Plant, VPP)進行研究與試驗，尋求低成本、低碳並具穩定性之解決方案。本文以國外需求面與 DER 整合相關研究為出發點，探討發展成熟之商業模式案例，及參與電力市場機會與挑戰，做為我國發展 DER 整合與 VPP 之參考。

Abstract

Under the trend of global net zero and energy transformation, distributed energy resources (DERs) such as renewable energy, energy storage, and electric vehicles are massively integrated into power grids. Despite of serving as an effective resource, DER nevertheless makes a power system more difficult to maintain supply and demand in balance, due to the characteristics of intermittency and low visibility, compared to traditional power plants. In order to properly control DERs, advanced countries such as Europe and the United States have conducted researches and experiments on DER integration and virtual power plants (VPPs) to explore low-cost, low-carbon and stable solutions. The contents of this article include integration of demand-side and DER resources, cases of mature business models adopted in foreign countries, and the opportunities and challenges of participating in electricity markets, to serve as reference for the development of DER integration and VPPs in Taiwan.

關鍵詞(Key Words)：需求面管理(Demand Side Management)、分散式能源(Distributed Energy)、商業模式(Business Model)、資源聚合(Resource Aggregation)、虛擬電廠(Virtual Power Plant)。

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研析國內外低壓需量反應商業服務模式

Business Model for Low-Voltage DR Participants

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摘要

國外住商用戶需量反應推動經驗，小型低壓用戶降低空調用電確實可透過聚沙成塔方式達成抑低用電成效，除可降低電業供電壓力，減少發電需求，用戶亦可獲取獎勵回饋金，達成電業與用戶雙贏局面。針對低壓用戶調整彈性偏低的性質，需量反應若結合能源管理系統及智慧家電，使電器自動依照電價高低調節使用情形，減少傳統人力操控的不便，將有助於提升該等用戶管理用電的彈性及需量反應措施之實施效益。本文期望藉由國外低壓需量反應方案推動經驗，參考其方案內容以及第三方服務商之合作模式，以提出適用我國之可行商業模式建議。

Abstract

Based on the experience of demand response (DR) of foreign residential and commercial customers, small-scale low-voltage (SSLV) customers when mass gathering may help electric utilities achieve the effect of peak load shaving. In addition to reducing the peak demand and the pressure of maintaining supply and demand in balance, DR participants can also obtain rewards of rebates to achieve a win-win situation for the electric utility and the customers participating in DR programs. In view of the low adjustment flexibility of DR programs, when combined with energy management systems and smart home appliances to automatically adjust the usage of appliances, according to the electricity prices of different time periods, the flexibility of SSLV customers and benefits of DR programs may thus increase, and the inconvenience of traditional manual control on the contrary decrease. In this article, we propose a feasible business model applicable to Taiwan based on the experience of low-voltage DR programs in foreign countries such as California and Japan.

關鍵詞 (Key Words)： 需量反應 (Demand Response, DR)、需求面管理 (Demand-side Management)、用戶群代表 (DR Aggregator)。

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產業用戶需量反應潛力訪查與案例分析

DR Potential Investigation and Case Analysis of Industrial Users

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摘要

本文以產業用戶為標的，藉由 Esgator 模式與台電公司區營業處合作，進行同產業性質用戶之訪查，並依其製程程序、設備類型，彙整建立各類型產業之製程特徵，評估其執行需量反應之潛力作法。有別於採取以 AMI 資料分析、問卷調查方式評估需量反應潛力，因未考量產業製程實際情形，而與用戶現場應用發生落差，本文所建立之程序已實際運用於 21 產業 63 用戶，製程特徵均彙整自用戶訪視結果，本文將有助於電業及能源服務業於需量反應用戶招募工作之推展。

Abstract

This article takes industrial users as the target, and cooperates with Taipower's regional sales offices, by the aid of the Esgator model, to conduct interviews with users of the same industry nature, and according to their process procedures and equipment types, collect and establish the process characteristics of various types of industries, and evaluate their potential to execute demand response (DR). Apart from using AMI data analysis and questionnaire survey to evaluate the potential of DR, the procedures established in this study have been actually applied to 63 users in 21 industries, and the characteristics of the industrial process are collected from on-site interviews. The contents of this article may serve as reference for the electric utilities and energy service companies (ESCOs) in Taiwan for future DR participant recruitment.

關鍵詞 (Key Words)：需量反應(Demand Response)、生產製程(Manufacturing Process)、用電型態(Load Pattern)。

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自動需量反應 OpenADR 用戶端系統開發與應用

Development and Application of OpenADR Client System for Automated Demand Response

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摘要

本論文提出符合自動需量反應通訊協定Open Automated Demand Response(OpenADR)之Virtual-End-Node(VEN)用戶端系統開發與應用。儘管現有VEN用戶端系統提供高執行效率、易維護、以及易整合等好處，然而因系統欠缺資安考量，導致降低第三方系統整合商使用意願。因此，為強化資安防護，本論文精進現有OpenADR 2.0b VEN用戶端系統，導入HTTPS安全網路傳輸協定以及RESTful API身份認證機制，確保資料傳輸安全。此外，為提昇VEN用戶端系統的實用價值，本論文選定二個現行運作之自動需量反應VTN平台，進行通訊對接，驗證VEN用戶端系統可實際參與需量反應方案。本論文開發之VEN系統成功通過OpenADR Alliance認證工具全部測試項目，包含註冊(Registration)、需量事件(Event)、報告(Report)、排程(Opt)服務、一般(General)以及Profile A之相關測試項目，以確保訊息傳遞符合OpenADR 2.0b通訊協定。

Abstract

This paper proposes the development and application of the VEN (Virtual-End-Node) client system that complies with the OpenADR (Open Automated Demand Response) communication protocol. Although the existing VEN client system provides benefits such as high execution efficiency, easy maintenance and integration, the lack of information security considerations in the system reduces the willingness of third-party system integrators to use it. Therefore, in order to strengthen information security protection, this paper refines the existing OpenADR 2.0b VEN client system, introduces the HTTPS secure network transmission protocol and the RESTful API authentication mechanism to ensure data transmission security. In addition, to enhance the practical value of the VEN client system, this paper selects two currently operating automated demand response VTN platforms for communication to verify that the VEN client system can actually participate in demand response programs. The VEN system developed in this paper has successfully passed all the test items of the OpenADR Alliance certification tool, including registration, demand event, report, Opt service, general and Profile A, to ensure that the messaging conforms to the OpenADR 2.0b protocol.

關鍵詞(Key Words)：自動需量反應(Automated Demand Response)、開放自動需量反應通訊協定(OpenADR)、虛擬終端節點(VEN)、虛擬頂端節點(VTN)。

我國時間電價調整試辦方案之效益分析

Benefit Analysis of a Time-of-Use Rate Adjustment Pilot Program in Taiwan

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摘要

隨著太陽光電大量導入後，淨尖峰逐漸形成鴨子曲線型態，台電公司推出新時間帶電價供用戶選用作為因應，以降低夜晚供電容量吃緊問題，並搭配電價保護機制做為配套措施，使選用之用戶得以無風險調整用電型態，同時思考未來如何有效達到所有用戶溝通與宣導。除電價尖離峰時段之調整外，亦參考國外電業作法，針對再生能源增長以及電源結構改變而調整相關電價制度，以作為我國未來精進電價之參酌。

本研究以新時間帶電價試辦方案為主軸，透過調整電價費率並將尖峰時間帶挪移至傍晚，引導用戶改變電能使用，分析試驗用戶用電行為變化、參與影響及滿意度，以掌握試行計畫用戶效益；同時也蒐集國外電價因電源結構改變之電價方案相關資訊，綜整各項國內外資訊，並進一步探討不同電價方案之下的目標用戶，提出更加符合用戶與電業需要的電價方案建議，創造雙贏成果。

Abstract

With the introduction of a large number of solar photovoltaic energy, the net peak load of the power system in Taiwan has gradually formed a so-called Duck Curve. To deal with this situation, Taipower introduced a pilot Time-of-Use (TOU) rate for users to choose as a response to mitigate tight power supply at night; in parallel with a price protection mechanism for users to choose to adjust their electricity consumption patterns without risk; at the same time, think about how to effectively communicate and promote to all users in the future. In addition to the rate adjustment of on-peak and off-peak periods, in this study we refer to the practices of foreign power companies to adjust the relevant electricity rates in response to the growth of renewable energy and changes of power supply structure, as a reference for Taiwan.

By adjusting the electricity tariff and shifting the peak load time zone to the evening, this study aims to guide users to change their behaviors of energy use, and analyze the changes in the test users' electricity consumption behaviors, participation impact and satisfaction. At the same time, we collect information on foreign electricity rates due to changes in power supply structure, integrate domestic and foreign information, and identify target users under different schemes to propose tariffs that are in line with the needs of users and Taipower so as to create a win-win results.

關鍵詞 (Key Words)：時間電價(Time-of-Use Rate)、鴨子曲線(Duck Curve)、再生能源(Renewable Energy)、效益評估(Benefit Evaluation)、時間帶調整(Timeframe Shifting)。

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電動車參與電力市場之用電管理及商業模式應用趨勢 研析

Research on the Energy Management and Business Model of Electric Vehicles Participating in
Electricity Market

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摘要

時值國際能源轉型趨勢，再生能源、儲能系統及需量反應等技術發展，各國紛紛投入智慧電網相關技術之研發，以及電力市場用電管理。虛擬電廠整合需求端之可控電力結合資通技術以構成虛擬電廠聚合服務系統，並於電力市場及電網間發掘更多效率提升與靈活應用的潛力。隨著載具電動化的加速發展，近年各國研究如何透過 V2G 充電行為管理與智慧化方式舒緩充電行為可能造成對電網之衝擊以符合國際電業潮流，並可作為因應再生能源間歇性之解決方案。本研究蒐集國外電動車/電動樁參與電力市場之用電管理及商業模式，供我國未來規劃之參考。

Abstract

Under the background of worldwide energy transition and booming development of renewable energy (RE), energy storage system and demand response, many countries have invested in the research and development of smart grid related technology and energy management of electricity consumption. Virtual power plants (VPPs) integrate controllable demand-side resources and information communication technology to form a virtual aggregation service system to explore the potentials for electricity market efficiency and power system flexibility improvement. With the accelerated development of vehicle electrification in recent years, many countries have studied how to relieve the impacts of EV charging through smart V2G charging and behavior management, to be in line with the worldwide trend and serve as a solution dealing with RE intermittency. In this research, we collect the electricity consumption management and business models of electric vehicles (EVs) and charging piles in foreign countries to serve as a reference for the future planning of Taiwan.

關鍵詞 (Key Words)： 虛擬電廠(Virtual Power Plant)、電動車(Electric Vehicle)、商業模式(Business Model)。

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台灣電動巴士區域負載分析

Regional Load Analysis of Electric Buses in Taiwan

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摘要

因應 2050 淨零排放目標及交通部「2030 年客運公車全面電動化」政策，本研究建立台灣電動巴士區域負載分析模組，評估六都區域電動巴士至 2030 年各年度可能新增負載。研究透過設計問卷針對六都客運業者進行調查，並訪問六都(台北市、新北市、桃園市、台中市、台南市、高雄市)交通局及客運業者，以質性研究方式蒐集各區域市區公車特性、釐清關鍵參數並建立分析模組。本研究顯示，2030 年六都市區公車電動化可能的新增區域負載如下：台北市將新增 125.93~277.05 百萬度電、新北市將新增 105.16~231.35 百萬度電、桃園市將新增 29.11~64.03 百萬度電、台中市將新增 63.65~140.02 百萬度電、台南市將新增 19.93~43.85 百萬度電、高雄市將新增 38.42~84.52 百萬度電。本研究之成果可作為未來電網因應策略及需求面管理措施政策之制定參考。

Abstract

In response to the 2050 Net Zero Emissions (NZE) target and the Ministry of Transportation and Communications' policy of "full electrification of passenger buses by 2030", this study, using a system dynamics software titled Vensim, established a regional load analysis module for electric buses in Taiwan to evaluate the annual electricity demand increase of electric buses in six major cities (Taipei, New Taipei, Taoyuan, Taichung, Tainan, and Kaohsiung) by 2030. The study conducted surveys on passenger transport operators through the design of questionnaires, and interviewed the traffic bureaus and passenger transport operators in those cities to collect regional characteristics of passenger buses and verify key parameters so as to establish an analysis module. The results of this study show that the demand increase of electric buses in the six cities due to electrification are as follow: Taipei City will add 125.93~277.05 GWhs, New Taipei City will add 105.16~231.35 GWhs, Taoyuan City will add 29.11~64.03 GWhs, Taichung City will add 63.65~140.02 GWhs, Tainan City will add 19.93~43.85 GWhs, Kaohsiung City will add 38.42~84.52 GWhs. The results of this study may serve as a reference for formulating the coping strategies of the power grid and policy for demand-side management measures.

關鍵詞(Key Words)：電動巴士(Electric Buses)、需求面管理(Demand-side Management)、負載分析(Load Analysis)、系統動力學(System Dynamics)。

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整合表後多元資源成為可調度虛擬電廠

Integrate Multi Behind-the-Meter Resources into Dispatchable Virtual Power Plant

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摘要

2020 年美國聯邦能源管制委員會(Federal Energy Regulatory Commission, FERC)頒布 2222 號行政命令(Order 2222)，允許多元分散式能源參與電力市場，以快速、有效地提升電網韌性和彈性，來因應氣候變遷的挑戰。依 Guidehouse Insights 預估^[1]，因為分散式能源電力電子技術飛快成長而大量併網，西元 2029 年時，全球彈性能源容量(Flexible Energy Capacity)，將從 2020 年之 55.8GW 成長 3 倍至 150.3 GW。西元 2023 年大年初四，國內風電加上光電瞬時滲透率已首度突破 31.2%。隨著可再生能源的相繼投入，相較於傳統能源，電廠已轉變為相對分散式且複合式的型態。台電公司已經為此開始重新調整電源供給規劃及發/輸/配/售電營運和商業模式，為電力能源行業的持續快速增長作好準備。過去兩年，國內的電力交易平台，提供包含調頻、即時和補充備轉的電網服務，已驗證其對電網發揮關鍵作用，同時台電也於去年勇奪「台灣企業永續-創新成長領袖獎」^[2]。

Abstract

In 2020, the U.S. Federal Energy Regulatory Commission (FERC) issued Executive Order 2222, which allows multiple distributed energy resources (DERs) to participate in electricity markets to quickly and effectively improve the flexibility and resilience of power grids to cope with climate change challenges. According to the estimate of Guidehouse Insights^[1], due to the rapid growth of distributed energy resource related technologies and a large number of grid connections, by 2029 the market of global flexible energy capacity will triple from 55.8 GW in 2020 to 150.3 GW in 2029. On the fourth day of the Lunar New Year in 2023, the instantaneous penetration rate of wind power plus photovoltaics in Taiwan has exceeded 31.2% for the first time. With the continuous input of renewable energy, compared with traditional energy, power plants have transformed into a relatively decentralized and composite type. For this reason, Taipower has begun to readjust the planning of power supply, operation models of generation, transmission, distribution and sales, and business models to prepare for the sustained and rapid growth of electric power industry. In the past two years, domestic electricity trading platforms have provided grid services, including frequency regulation, spinning and non-spinning operating reserves, which have played a key role for the power grid.

關鍵詞(Key Words)：商業模式(Business Model)、虛擬電廠(Virtual Power Plant, VPP)、聚合商(Aggregator)、產消者(Prosumer)、表後(Behind-the-meter, BTM)、分散式資源(Distributed Energy Resource, DER)、需量反應(Demand Response, DR)、能源管理系統(Energy Management System, EMS)。

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供需資源整合之評估與實作：以畜電共生為例

Integration of Supply-side and Demand-side Resources: Taking the Livestock and Electricity Symbiosis as an Example

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摘要

為了解分散式電網國際趨勢以協助國內能源轉型，本計劃調研國際分散式能源發展概況，包括日本、美國與澳洲，並歸納出若欲發展分散式能源之條件。

本計畫與中興大學合作，實際於中興畜牧場設置自發自用太陽能、蓄電池組、需量反應調控設備與聯齊 AI 能源管理系統，亦導入廢水產氫設施。透過導入以上資源，不僅提升能源應用效率外，一年也可減少 37 噸碳排放量。

本計劃發現試驗場域太陽光電自發自用占比高時，經濟效益最佳；若比較最大光電設置之銷售模式，在國內現行狀況下，全部售電效益最佳，部分自發自用次之，全部躉售最差。

透過場域實證與國內外產業調查，針對國內農漁牧業與電共生提出發展建議：建議農漁牧聚落先提升自身能源運用之效益，再盤點並整合鄰近區域供需資源，形成完整分散式能源管理系統，降低對中央電網之依賴，未來甚至可參與電力交易市場，創造額外效益。

Abstract

To understand the global trend of decentralized grid in order to assist the energy transition in Taiwan, this project investigates the development of distributed energy resource (DER) in Japan, the United States of America and Australia, and summarizes the conditions for developing DER.

This project cooperates with National Chung Hsing University to actually establish self-generated solar energy, energy storage system, demand response control equipment, NextDrive AI energy management system (EMS) at Zhongxing Animal Farm, as well as introduce waste water hydrogen production facilities. Through importing the above resources, the efficiency of energy application is improved, and 37 tons of carbon emissions reduced a year.

In addition, from the simulated data of the pilot site, this project evaluates the economic benefits of different system capacity under energy management system-controlled mode and concludes that the economic benefit is the best when the proportion of self-use is high. As for the sales models of the largest PV installations, under current domestic situations, the profit and internal rate of return

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(IRR) of all for sale model is the highest, followed by partial self-use model; and surplus power sold to the grid with feed-in-tariff has the lowest profit and IRR.

Through field demonstration and domestic and foreign industry surveys, we suggest that the industries of agriculture, fishery and animal husbandry should first improve their efficiency of energy use, then take inventory and integrate the supply and demand resources of adjacent areas to form a complete distributed EMS to reduce dependency on the central power grid, and participate in electricity markets to create further benefits.

關鍵詞(Key Words)：再生能源轉型政策(Renewable Energy Transition Policy)、去中心化電網(Decentralized Grid)、產消者(Prosumer)、分散式能源商業模式(Distributed Energy Resource Business Model)、營農型太陽光電綠能農業設施(Agrivoltaic Farm)。

分散式資源整合圖資平台研究

Research on Integrative Geospatial Information System for Distributed Energy Resources

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摘要

近年來為配合政府再生能源政策，台電公司發展輸電級 GIS 視覺化平台(TGIS)及配電級饋線 GIS 視覺化平台(FGIS)，目前皆已上線提供服務，考量不同使用者互動體驗，採用開放式圖台技術進行 TGIS 開發，可較快速支援圖資資訊更新；採用圖磚技術進行 FGIS 開發，可較高系統效能提供服務。

然因再生能源應用越來越廣泛，為滿足各類圖資需求，使得有必要發展一套能夠管理與運用再生能源地理圖資的系統，能整合各類資訊，提供再生能源圖資製作，且將圖資產製成圖磚或影像並發布成相應的圖資服務，另外也能將原始資料處理與篩選後，發布成資料 API，同時，透過圖資服務與資料 API 服務的相互結合，方便、迅速且正確地建立對內或對外展示之網頁圖台，以作為再生能源政策擬定、併網規劃、資料研究等相關工作之輔助工具。

Abstract

In recent years, in order to cooperate with the government's renewable energy (RE) policy, Taipower has developed a transmission-level GIS visualization platform (TGIS) and a distribution-level feeder GIS visualization platform (FGIS). Both of the platforms have been launched to provide services. In consideration of different user interaction experience, the use of open map platform technology for TGIS development can support map information updates more quickly. And the use of map tile technology for FGIS development can provide services with higher system efficiency.

However, due to the increasing installation of renewable energy, in order to meet various needs of geospatial information, it is necessary to develop a system to manage and integrate various RE geospatial data, and through a series of data processing turn geospatial data into map tiles or images to publish as corresponding map services. In addition, the original data can be processed, screened, and released into a data API. On the other hand, through the mutual combination of map data and API services, a web page map platform for internal/external display, can be established more conveniently, quickly and precisely, to serve as an auxiliary tool for RE policy formulation, grid connection planning, data research, among other related works.

關鍵詞(Key Words)：輸電級 GIS 視覺化平台(TGIS)、配電級饋線 GIS 視覺化平台(FGIS)、可併網容量(Hosting Capacity)、地理資訊系統(GIS)、開放原始碼(Open Source)。